SPECIFICATIONS FOR INCINERATOR TESTING AT FEDERAL FACILITIES

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Bureau of Disease Prevention and Environmental Control
National Center for Air Pollution Control

SPECIFICATIONS FOR INCINERATOR TESTING AT FEDERAL FACILITIES

PUBLIC HEALTH SERVICE SPECIFICATIONS
FOR INCINERATOR TESTING TO DETERMINE COMPLIANCE OF FEDERAL
FACILITIES UNDER THE CODE OF FEDERAL REGULATIONS,
TITLE 42, CHAPTER 1, SUB-CHAPTER F, PART 76.

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Abatement Program
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I. INTRODUCTION

The following test procedures are recommended for use in determining whether an incinerator meets the air pollution emission standards of the Federal Code as detailed in Section 2, herein. These test procedures are applicable to the following types of incinerators:

1. Multiple-chamber incinerators burning less than 2,000 pounds per hour of general refuse.

2. Multiple-chamber incinerators burning pathological waste.

3. Single-chamber incinerators, except flue or chute fed incinerators, burning either general refuse or pathological waste.

In some instances, these incinerators may be equipped with scrubbers or afterburners to reduce emissions to the atmosphere. These procedures may still be used where such devices are employed.

Many incinerator operating variables, such as type of waste, charging, and stoking processes, affect emission levels. To minimize the effects of these variables on emissions, standard procedures described herein have been adopted. In addition, since sampling equipment and analytical procedures also influence results, existing test methods were reviewed and applicable parts of these methods were incorporated in these procedures.

The test procedures included herein are taken in part from the as yet unpublished, "Interim Guide to Good Practice for Selected Incinerators for Federal Facilities" and, as such, are subject to revision. Equivalent test procedures or equipment may be used for purposes of determining compliance, provided that they are approved by the Federal Facilities Section, Abatement Program, National Center for Air Pollution Control, Washington, D. C.

2. DETERMINING COMPLIANCE

2.1 GENERAL

In the case of new incinerators of a design other than those recommended in the Interim Guide or incinerators that are to be upgraded to meet the Federal Code, it should be agreed with the supplier or person modifying the incinerator that the procedures described herein will be used to determine compliance prior to purchasing the incinerator or contracting for its modification. In any event, an engineer from the Abatement Program shall be present at every test as an observer.

A testing organization, private or governmental, subsequently called "tester," which has had experience in testing incinerators to determine their emissions to the atmosphere or can establish competency to conduct tests, may conduct acceptance tests.

2.2 STANDARDS FOR PARTICULATE EMISSIONS

An incinerator will be deemed to have met the particulate emission standards with regard to grain loading if, upon being tested by the procedures described herein, it is found to emit, as the average of two runs, concentrations of particulate matter not in excess of that given in subsections 2.2.1 and 2.2.2

2.2.1 Incinerators of 200 Pounds Per Hour and Over

Incinerators, existing or new, having burning rates equal to or greater than 200 pounds per hour shall not exceed 0.2 grain of particulate matter per standard cubic foot of dry flue gas corrected to 12 percent carbon dioxide (without the contribution of carbon dioxide from auxiliary fuel), and shall not normally include particles larger than 60 microns.

2.2.2. Incinerators Under 200 Pounds Per Hour

Incinerators, existing or new, having burning rates of less than 200 pounds per hour shall not emit more than 0.3 grain of particulate matter per standard cubic foot of dry flue gas corrected to 12 percent carbon dioxide (without the contribution of carbon dioxide from auxiliary fuel).

2.3 STANDARDS FOR VISIBLE EMISSIONS

2.3.1 Existing Incinerators

For existing units, except during startup or stoking, the density of any emission to the atmosphere shall not exceed Number 2 on the Ringelmann Scale or Public Health Service Smoke Inspection Guide.

2.3.2 New Units

For new units, except during startup or stoking, the density of any emission to the atmosphere shall not exceed Number 1 on the Ringelmann Scale or Public Health Service Smoke Inspection Guide.

3. WASTE PREPARATION

Tests on general-refuse-burning incinerators shall be conducted while burning the standard waste described below or its equivalent as specified by the Federal Facilities Section. Tester shall prepare the waste so that the components do not vary more than 10 percent from the percentage of each component specified below:

Material	Percent by weight
Corrugated cardboard shredded into 1/2-inch strips	23
Newspaper cut into strips 2 by 12 inches	22
Magazines cut along bindings into pieces 2 by 12 inches	17
Brown paper, wax-coated or impregnated paper, and plastic-coated paper, equal portions of each, in pieces no larger than 6 by 6 inches.	15
Raw potatoes cut into slices approximately 1/2 by 1/2 by 3 inches	23
	100

For general-refuse incinerators, the refuse is to be packaged in paper bags of sizes between 1/10 and 1/20 of the volume of the primary chamber. All bags are to be weighed to the nearest quarter pound and marked. During testing, the weights should be recorded as the bags are charged. For general-refuse incinerators of 300 pounds per hour or over, however, the waste may be packed in cardboard boxes; the weight of the bag or box will be considered as part of the brown paper or cardboard required in the charge.

Tests on pathological incinerators shall be conducted while burning animals or other pathological waste of a nature that would normally be charged to the incinerator. In testing pathological incinerators all animals over 5 pounds should be placed in separate plastic bags, weighed to the nearest one-half pound, and have its weight clearly marked on the bag, prior to startup of the incinerator. Smaller animals, such as guinea pigs, rats, mice, and rabbits, should be combined to form 3-pound charges in plastic bags, weighed, and marked as detailed above. All limbs, organs, and other human tissue should be charged in plastic bags, containing not less than 3 pounds of material, with the weight clearly marked to the nearest quarter pound.

Tests on incinerators burning Types 3, 5, and 6 wastes[1] shall be conducted while burning the waste that will be normally fired into the incinerator.

4. PRELIMINARY TEST ARRANGEMENTS

Tester shall notify the Federal Facilities Section at least 30 days prior to the test, so that an engineer from the Abatement Program can be present as an observer at every test.

Prior to the test, tester is to clean the incinerator ignition chamber, ash pit, and combustion chambers of all ashes and debris; and the grates or hearth of any unburned residue or ashes. Tester will also inspect all gas burners, dampers, fans, air port dampers, and other appurtenances to determine whether they are functioning properly. Tester is also to clean out and inspect any scrubber with particular attention to scrubber nozzles to see that they are not plugged. If any of the foregoing are inoperative, malfunctioning, or in need of repair, tester will inform the proper parties so that all appurtenances may be made to function properly before the test.

5. TRIAL RUN

Tester shall operate each incinerator for a 1-hour trial run, preferably immediately prior to the day of actual testing, so that time will be ample to make any corrections or calculations required before the actual tests. During the trial run the incinerator shall be operated in the same manner as during the actual test. The purposes of the trial run test period are as follows:

1. To adjust the incinerator to produce proper combustion chamber draft.

2. To establish charging procedures.

3. To establish rated or maximum burning rate of incinerator.

4. To determine the stack gas velocity profile.

5. To determine the correct nozzle size for isokinetic sampling.

5.1 DRAFT ADJUSTMENT

Before attempting to perform any of the other tasks to be accomplished during the trial run, tester shall first adjust the draft at the primary chamber air ports to between 0.1 and 0.25 inch of water column, or to the setting listed in the manufacturers' instructions. The draft may be regulated by adjusting any of the following devices:

1. Barometric damper.
2. Guillotine damper.
3. Butterfly damper.
4. Fan.

While adjusting the draft, tester should operate the incinerator at its rated capacity if possible and use the burners that are to be operated during the test run.

5.2 CHARGING PROCEDURE

During the trial run, tester will determine whether charging procedures as specified herein are suitable for each particular incinerator. If not, tester will consult with the Federal Facilities Section, and such procedures may be modified as necessary.

In the case of pathological incinerators, all waste charged shall be exposed to the flames of the primary burners without blocking the burner port and shall be distributed as evenly as practicable over the hearth.

5.3 DETERMINATION OF CHARGING RATE

During the trial run tester will establish the charging rate for the incinerator. This shall be the rated capacity or the maximum rate, not in excess of the rated capacity, at which none of the following conditions occur:

1. The physical volume of the incinerator is exceeded (the flame port should not be obstructed.)
2. Gases are beginning to puff out of the incinerator.
3. Positive pressure appears at the underfire air ports in the ashpit or at the overfire air port. If such a positive pressure appears or the incinerator puffs out, then the charge rate shall be reduced until the incinerator does not puff out or operates with a negative draft in the chamber in which the draft is being measured.
4. The burndown period for organic material does not extend more than 15 minutes past the 1-hour test period.

5.4 GAS VELOCITIES

By traversing for gas velocity and temperature at the sampling locations, tester shall determine the expected velocity profile and the size nozzles to be used during the test.

5.5 LOG OF TRIAL RUN OPERATIONS

Tester will also keep an operating log for the trial run to record all of the operating details of the run, such as time of lightoff, amount of waste charged, time and frequency of stoking, adjustment of air ports, time at which burndown is completed, and amount of residue. The original log of trial run data shall be submitted with the final report of the test.

6. INCINERATOR OPERATION DURING TEST RUNS

6.1 LOG OF OPERATIONS

Tester shall keep an operating log for each run in which all of the operating details of the test run are recorded, such as time of lightoff, amount of waste charged, time and frequency of stoking, adjustment of air ports, opacity readings, time burners operate, duration of test, amount of residue estimated. The original log shall be submitted with the report of the incinerator test. Any abnormal conditions should be noted and explained.

6.2 BURNERS

For incinerators equipped with burners, the fuel rate in cubic feet per hour of natural gas or other auxiliary fuel should be measured, and the time the burners are in use during each run should also be recorded. If this technique cannot be used and approval is obtained from the Federal Facilities Section, the burners can be operated prior to the test itself without any refuse in the incinerator. The amount of carbon dioxide in the flue gas from burners can then be determined by:

1. An Orsat analysis.

2. A velocity traverse.

3. Gas temperature and moisture content measurement.

6.2.1 General-Refuse Multiple-Chamber Incinerators

When the standard waste described herein is being burned in a multiple-chamber incinerator, such burners, if any, as the designer wishes to use may be employed. In any event, secondary burners, if present, should be used. Where it may be necessary to turn off a primary burner occasionally, the carbon dioxide contribution from both primary and secondary burners shall be determined individually for each run.

6.2.2 Pathological Multiple-Chamber Incinerators

When pathological waste is being burned, such burners shall be used as the designer wishes; otherwise, all burners should be used. Where it may be necessary to turn off a primary burner occasionally, the carbon dioxide contribution from both primary and secondary burners shall be determined individually for each run.

6.2.3 Single-Chamber Incinerators

When the standard waste described herein is burned in a single-chamber incinerator, such burners and/or afterburners as the designer wishes to use may be employed. In any event, afterburners, if present should be used.

Where it may be necessary to turn off a primary burner occasionally, the carbon dioxide contribution from both primary and auxiliary burners shall be determined individually for each run.

If the incinerator is used for pathological waste, it will, of course, be necessary to use the primary chamber burner.

6.3 PREHEATING PERIOD

6.3.1 General-Refuse Multiple-Chamber Incinerators

Incinerators should be preheated for 1 hour before testing begins, or until the temperature in the expansion chamber reaches 1,000°F. During the preheat, the incinerator should be operated as it will be during the test.

6.3.2 Pathological Multiple-Chamber Incinerators

Incinerators should be preheated with their secondary burners before charging of refuse is begun. Preheating should continue until the temperature in the expansion chamber reaches 1,000°F or attains some lesser steady-state value. An hour is usually the maximum preheat time needed.

6.3.3 Single-Chamber Incinerators

No preheat period is necessary for this type of unit, unless the seller wishes to have the unit preheated. Where such units are equipped with afterburners, the afterburner should be preheated before testing begins to a minimum of 1,200°F, or for a minimum of 1 hour, if the gas temperature, as measured at the exit of the afterburner, does not reach 1,200°F.

6.4 CHARGING PROCEDURES

6.4.1 General-Refuse Multiple-Chamber Incinerators

Waste is to be weighed and charged or thrown into the incinerator in packages prepared as described in Section 3.

The incinerator is to be charged every 5 minutes. In those cases where the incinerator has a charging door, i.e., not top-charged through a chute, the door is to be closed immediately after charging.

The size of each charge, as measured by the number of packages of waste thrown into the incinerator, is to be approximately 1/12 the total weight of refuse the incinerator is rated as capable of burning in 1 hour, unless tester determines that the incinerator will not burn at its rated capacity during the trial run. In this case, the amount of each charge will be reduced accordingly so that unburned refuse does not accumulate in the incinerator, i.e., a relatively constant fuel bed must be maintained in the incinerator.

If unburned organic material remains after the end of any test run the amount of material so remaining shall be estimated and deducted from the weight of material consumed in the incinerator during the test. The capacity or burning rate will be based on these results and reported as such.

For incinerators with a rated capacity of 300 pounds per hour and over, the waste may be placed in cardboard boxes of comparable size instead of paper bags.

Stoking, when necessary, should be coordinated with each and every charge period and should be for equal increments of time throughout the test.

In no case should waste be burned at a rate in excess of the rated capacity of the incinerator.

The grates should be cleaned out after the first test, but the ashpit need only be cleaned out if ashes accumulate to the point where the underfire air is obstructed.

A cooling period shall be allowed between runs so that the temperature in the expansion chamber may return to the value it had when the first run began.

6.4.2 Pathological Multiple-Chamber Incinerators

After the incinerator has been preheated according to Section 6.3, the waste shall be charged into the chamber and the primary burners ignited. The size of the original charge and any successive charges necessary to reach rated capacity or maximum capacity shall be that determined during the trial run, provided that waste shall not be burned in excess of the rated capacity of the incinerator. If, during any run, additional waste is added after the first charge, then the primary burner shall be temporarily turned off during such additional charging. If organic material remains after the end of any 1-hour test period, the amount of material remaining may be estimated and deducted from the weight of material charged to determine the amount of material consumed during the test. The capacity or burning rate will be based on these results and reported as such.

All waste charges shall be exposed to the flames of the primary burner(s), without blocking the burner port, and shall be distributed as evenly as practicable over the hearth.

6.4.3 Single-Chamber Incinerators

Follow the same procedures as those given in Section 6.4.1 for General-Refuse Multiple-Chamber Incinerators, for those single-chamber units burning general refuse, and the procedures of Section 6.4.2 for those units burning pathological waste.

6.5 SCRUBBERS

Scrubbers shall be operated in keeping with the manufacturer's recommendations during each run. The pressure drop across the scrubber and water circulation rate or water throughput rate shall be measured and reported in the operating log.

7. PARTICULATE SAMPLING

Each test shall consist of two runs. For pathological incinerators, each run shall be 1 hour. For test time of general multiple-chamber incinerators, consult specification available from the Federal Facilities Section. During each run, samples of the following pollutants will be collected for later analysis or measurement as specified: particulates, carbon dioxide, moisture content of the gases, oxygen, and adhesive paper samples. In addition, the temperature in the expansion chamber shall be measured and recorded, and a record made of visible emissions using the Ringelmann chart in accord with procedures in Bureau of Mines

Information Circular No. 7718 of the PHS Smoke Inspection Guide, used in accordance with the procedures in Title 42, Chapter 1, Sub-Chapter F, Section 75.2 of the Code of Federal Regulations.

7.1 VELOCITY TRAVERSE

The following material should be used to perfect the proper traversing procedures.[2]

MEASUREMENTS AND CALCULATIONS

Since the pitot tube measures velocity head only at the point in the gas stream where it is placed, readings must be made at a number of points in the stack cross section so that the average gas velocity may be calculated. The number of points to be used and their location can be readily determined in accordance with commonly accepted practice.

The cross-sectional area of the stack at the test station is divided into a number of concentric equal-area zones for circular stacks (Figure 1), or rectangular equal areas for rectangular stacks (Figure 2). The number of areas used depends on the flow pattern and the size of the stack. For circular stacks, with fairly uniform flow, the usual practice is to employ the number of areas shown in Table 1.

The traverse points for velocity head measurements are located in each area as suggested in Figures 1 and 2. With rectangular ducts or stacks, these points are at the center of each square area (Figure 2).

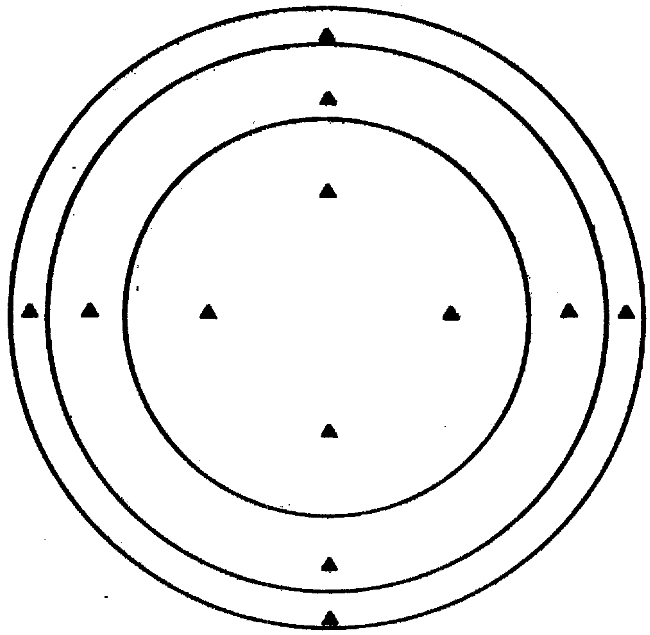


Figure 1. Cross section of a circular stack divided into three concentric equal areas, showing location of traverse points. The location and number of such points for a stack of given diameter can be determined by referring to Equation 1 or Table 2.

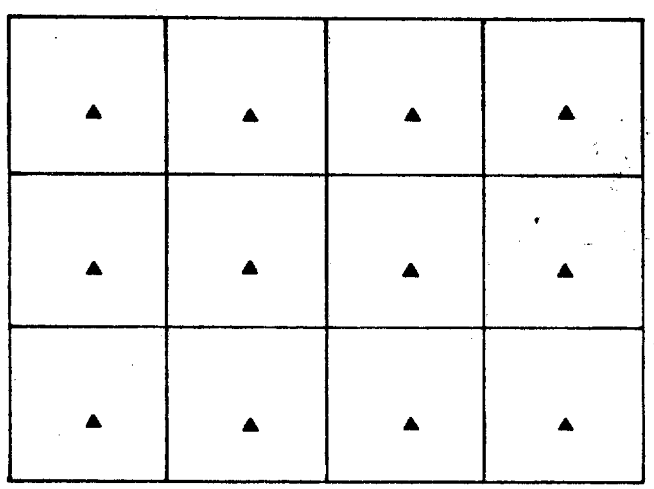


Figure 2. Cross section of rectangular stack divided into 12 equal areas, with traverse points located at the center of each area.

For circular stacks, the location of each point along a stack diameter is calculated from the expression:

$$P = 50 \left[1 - \sqrt{\frac{(2j - 1)}{2a}} \right] \qquad (1)$$

where:

P = Percent of stack diameter from the inside wall to traverse point.

a = Total number of areas being used.

j = Number of the area for which the location is being calculated, number 1, 2, 3, ... from the center outward.

This formula gives half of the values needed, with the remaining half being the differences of each percentage from 100. In practice, it is simpler to use a table such as Table 2 where the percentages have already been calculated for the most frequently encountered numbers of points and areas.

When test holes are necessary in circular stacks, two holes are made along diameters at right angles to each other. The holes are large enough for the insertion of the pitot tube, sampling probes, and thermocouples. In stacks over 6 feet in diameter, four test holes are preferred so that extensions on pitot tubes can be avoided. With thin-walled stacks, 2-1/2- to 3-inch-diameter holes are sufficient. For thick walls, larger holes are required unless a type S pitot tube is used.

Table 1. NUMBER OF EQUAL AREAS FOR VELOCITY MEASUREMENT IN CIRCULAR STACKS

Stack diameter, feet	Number of equal areas
1 or less	2
1 - 2	3
2 - 4	4
4 - 6	5
over 6	6 or more

Table 2. PERCENT OF CIRCULAR STACK DIAMETER FROM INSIDE WALL TO TRAVERSE POINT

Point number	Number of areas selected				
	2	3	4	5	6
1	6.7	4.4	3.3	2.5	2.1
2	25.0	14.7	10.5	8.2	6.7
3	75.0	29.5	19.4	14.6	11.8
4	93.3	70.5	32.3	22.6	17.7
5		85.3	67.7	34.2	25.0
6		95.6	80.6	65.8	35.5
7			89.5	77.4	64.5
8			96.7	85.4	75.0
9				91.8	82.3
10				97.5	88.2
11					93.3
12					97.9

In rectangular ducts or stacks, holes are located to conveniently traverse the centers of the areas with the pitot tube.

The areas as shown in Figure 2 are to be made as nearly square in shape as possible, and the minimum number of equal areas in rectangular stacks is to be as shown in Table 3. Each equal area shall not exceed 0.5 square foot.

Table 3. NUMBER OF EQUAL AREAS FOR VELOCITY MEASUREMENT IN RECTANGULAR AND SQUARE STACKS

Cross-sectional area, ft^2	Number of test points
<2	4
2 - 12	6 - 25
>12	>25

7.2 SAMPLING LOCATION

The sampling location should be at least eight stack diameters downstream from any bend, expansion, contraction, or visible flame in the stack or flue, and at least **two** diameters upstream from any bend and obstruction. When sampling at the exit of a stack or flue, the tester will install an extension at least **two** stack diameters long above the point at which the sample probe is inserted into the flue.

If the tester finds eight diameters impractical, the following rule of thumb may be employed. For a straight flue run of six to eight stack diameters in length, approximately double the number of sampling points. For a length of four to six stack diameters, approximately triple the number of points. The exact number of sampling points shall be determined from specifications available from the Federal Facilities Section. If the length of straight flue is less than four diameters, no valid traverse can be made.

All incinerators will be sampled isokinetically at each traverse point as described in Section 7.1 for equal time increments coinciding with the charging cycle as specified in Section 6.4. When pathological incinerators are sampled, the particulate sampling probe will be placed at one reference point in the stack throughout the 1-hour test. The position of the reference point shall correspond to the point of average stack velocity as determined by the pitot traverse of the preliminary run. For each run, sampling shall begin when the refuse for that run is ignited.

7.3 ISOKINETIC CONDITIONS

All particulate sampling should be conducted with $\pm$ 10 percent of isokinetic conditions.

Measurements of stack gas flow by pitot tube to determine isokinetic sampling rates shall have the following precision in the ranges indicated:

Range	Sensitivity
< 0.10 inch of water	0.001 inch of water
> 0.10 inch of water	0.01 inch of water

7.3.1 Sampling Rate

Sampling rate should be adjusted to maintain isokinetic sampling conditions; i.e., the velocity in the tip of the sample probe nozzle should equal the velocity in the stack at the sample point. The sampling rate shall be at least 0.5 standard cubic foot per minute.

In order to maintain isokinetic sampling at all times, the following procedure, or equivalent, shall be followed:

1. A calibrated pitot tube or similar device for measuring velocity pressure and a thermocouple or a similar device for measuring stack temperature ($\pm$ 5°F) should be attached to the sample-collection probe to measure velocity pressure and stack temperature at the sample point.

2. A family of curves for different stack temperatures should be prepared for each incinerator tested so that isokinetic sampling can be maintained by reading and adjusting the gas flow rate through the sample train orifice or a similar device, which has a maximum absolute error of less than 5 percent of the sampling rate. (Note: on an arithmetic graph the family of curves will be straight lines; therefore, only one point need be calculated to determine the location of each curve.) An example family of curves is shown in Figure 3.

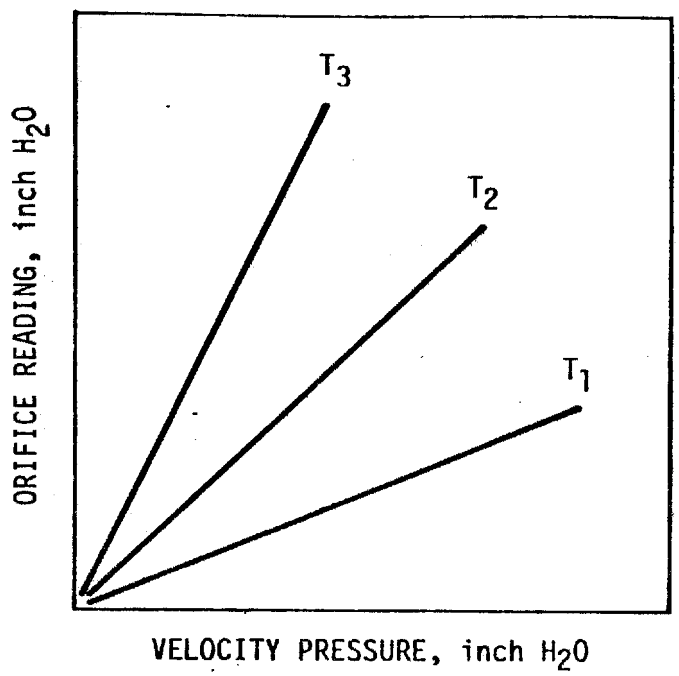


Figure 3. Relationship of velocity pressure to orifice reading for various stack temperatures to maintain isokinetic sampling conditions.

7.4 PARTICULATE SAMPLING TRAIN

The sampling apparatus shall consist of a probe, cyclone, filter, four impingers, dry gas meter, vacuum pump, and flow meter as shown in Figure 4, or equivalent as determined by the Federal Facilities Section. The stainless steel, buttonhook-type probe tip (1) shall be equipped with a 5/8-inch-diameter fitting so that it will connect by a stainless steel coupling (2) with Viton A O-ring bushings to the probe. When the stack temperature exceeds 500°F, asbestos string should be used as a gasket material. The probe (3) shall consist of 5/8-inch-outside-diameter medium-wall Pyrex glass tube with a ground-glass joint on one end. The glass probe should be logarithmically wound from the entrance end with 25 feet of 26-gauge nickel-chromium wire. During sampling, the wire shall be connected to a calibrated variable transformer to maintain a gas temperature of 250°F in the probe. The wire-wound glass tube shall be wrapped with fiber glass tape and encased in a 1-inch-OD stainless steel tube for protection. The end of the steel tube that does not have the balljoint protuding has a nut welded to it for connection to the stainless steel coupling used to attach the nozzle. The probe connects to a cyclone and flask (4) if used in the train. The cyclone connects to a very coarse fritted glass filter holder (5), which holds a 2-1/2- inch tared glass fiber filter. MSA type 1106 BH filter paper shall be used. The cyclone, flask, and filter shall be contained in an electrically heated enclosed box (6), which is thermostatically maintained at a minimum temperature of 250°F to prevent water condensation. Attached to the heated box shall be an ice bath (7) containing four impingers connected in series with glass balljoints. The first impinger (8) shall receive the gas stream from the filter. This impinger shall be of the Greenburg-Smith design modified

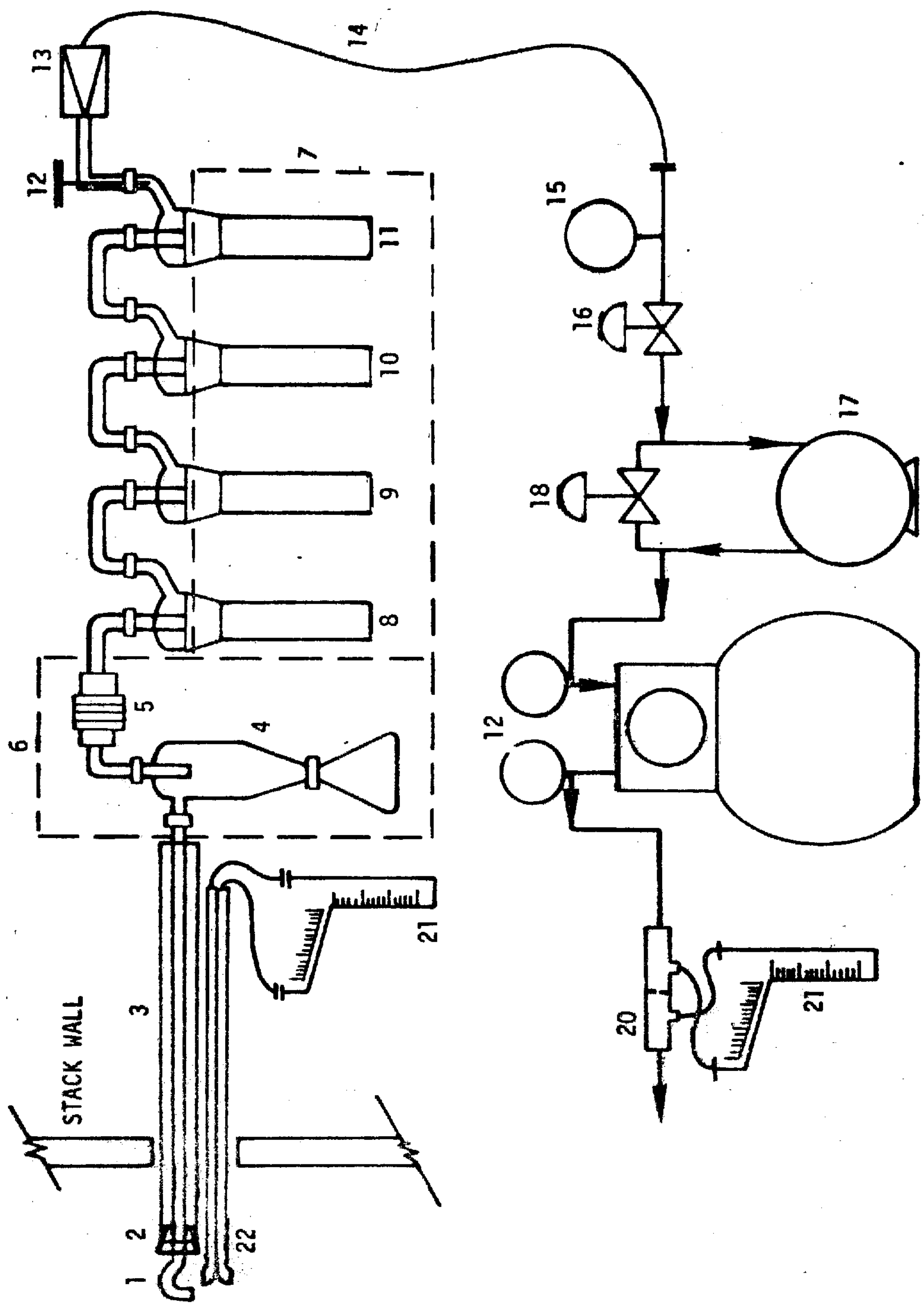


Figure 4. Particulate sampling train

by replacing the t[illegible] with [illegible]

inch from the bottom of the flask. This impinger shall be initially filled with 100 milliliters of distilled water. The second impinger (9) shall be a Greenburg-Smith impinger with tip, and also filled with 100 milliliters of distilled water. The third impinger (10), which is left dry, shall be a Greenburg-Smith impinger modified like the first. The fourth impinger (11) shall also be a Greenburg-Smith type modified like the first and contain approximately 175 grams of accurately weighed dry silica gel.

From the fourth impinger (11) the effluent stream flows through a check valve (13); flexible rubber vacuum tubing (14); vacuum gauge (15); a needle valve (16); a leakless vacuum pump (17), rated at 4 cubic feet per minute at 0 inches of mercury gauge pressure and 0 cubic feet per minute at 26 inches of mercury gauge pressure, and connected in parallel with a a by-pass valve (18); and a dry gas meter rated at 1 cubic foot per revolution (19). A calibrated orifice (20) shall complete the train and shall be used to measure instantaneous flow rates. The three thermometers (12) shall be dial type with a range of 25° to 125°F. A fourth thermometer in the heated portion of the box shall have a range up to 500°F. The dual manometer (21) across the calibrated orifice shall be an inclined-vertical type graduated in hundreths of an inch of water from 0 to 1.0 inch and in tenths from 1 to 10 inches.

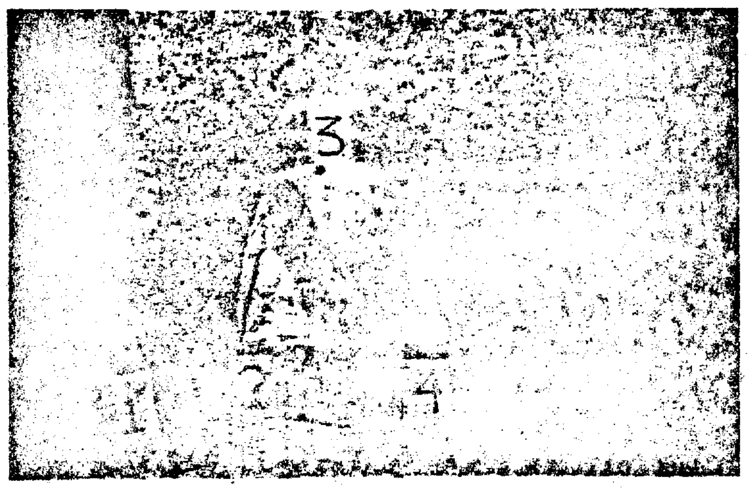
7.5 SOURCE TESTING FORMS

In order to insure acceptable operation of the incinerator and testing equipment, the tester will keep records at 5-minute intervals of physical parameters that influence the performance, e.g., pressure difference across

orifice and stack gas temperature. Forms for this purpose shall be obtained from the Federal Facilities Section, Abatement Program, National Center For Air Pollution Control, Washington, D. C.

8. SAMPLING FOR CARBON DIOXIDE

An integrated sample for carbon dioxide shall be collected over each run, utilizing the equipment in Figure 5.



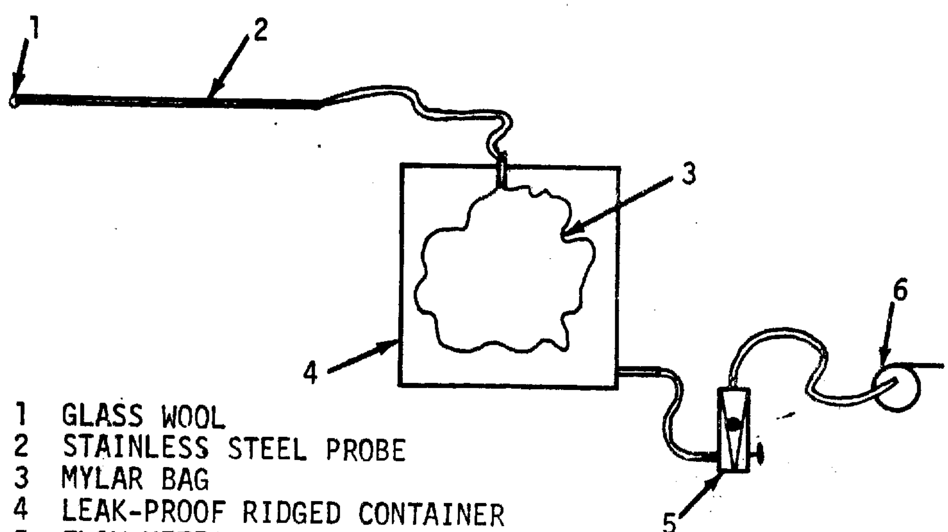
No. 1 Stainless steel probe
No. 2 1-mil Mylar bag
No. 3 Polyethylene container
No. 4 Vacuum pump and flow meter
No. 5 Orsat analyzer

Figure 5. Typical carbon dioxide sampling equipment

The Mylar bag (2) is inserted into the polyethylene container (3) or similar leakproof, rigid container. The inlet fitting on the Mylar bag is then pulled through a hole in the polyethylene container and sealed so that a vacuum can be drawn on the container. A piece of thick-walled tubing is attached to the fitting on the container and connected to a flow meter and vacuum pump (4). Upon pulling a vacuum in the polyethylene container, a sample will be drawn into the Mylar bag. The sample obtained is then analyzed with the Orsat analyzer (5).

Any convenient sampling rate can be used as long as the bag does not fill before the end of a test run. As stack velocity changes occur, the sampling rate should be adjusted in direct proportion to the changes.

Before sampling, the Mylar bag is evacuated with the vacuum pump. In addition, a piece of glass wool may be inserted in the end of the probe to prevent particulate from contaminating the bag. A flow meter placed between the probe and Mylar bag would help in detecting leaks in the bag and container.



1 GLASS WOOL
2 STAINLESS STEEL PROBE
3 MYLAR BAG
4 LEAK-PROOF RIDGED CONTAINER
5 FLOW METER
6 VACUUM PUMP

Figure 6. Schematic diagram of carbon dioxide sampling train.

The Orsat procedure gives volumetric concentrations to the nearest 0.2 percent by volume of each component in the stack gas, on a dry basis.

9. ADHESIVE PAPER TEST

The following is referenced from the Cincinnati Air Pollution Control Ordinance No. 119-1965.(Reference 3).

9.1 PREPARATION

Two-inch strips of Pli-a-Print R-135 adhesive paper shall be wrapped around a suitable holder of approximately 2-3/4 inches in diameter. The paper backing is to be kept in place until immediately prior to testing. Pli-a-Print R-135 adhesive paper is obtainable from Fasson Products, 250 Chester Street, Painsville, Ohio.

9.2 TESTING

A minimum of three adhesive paper samples shall be collected; one at approximately 1 minute after the startup, one toward the middle of the run, and another toward the end of the run. No samples shall be taken while the incinerator is being charged or stoked. The time each sample is collected shall be recorded. The adhesive surface of the paper shall be exposed to the flue gases for 1 minute or less. The sample shall be taken at the center of the flue and shall not be rotated while particles are being collected. Immediately after exposure, the sample shall be properly indentified and sprayed with a clear lacquer, such as JAPALAC 4010.

9.3 ANALYSIS

Using suitable magnification, tester shall determine the number of particles

60 microns and larger contained within 1 square inch of adhesive surface having the greatest particle deposit. The number of particles shall be the average of the count of 10 random fields within the 1 square inch.

10. VISIBLE EMISSIONS

The Ringelmann number of any black smoke shall be read as the smoke occurs, or at least every 10 minutes during each run. (See Section 7 for method of reading smoke.)

11. CLEANUP AND ANALYSIS FOR PARTICULATE TRAIN

11.1 CLEANUP

Proper care shall be exercised in moving the collection train from the test site to the cleanup area so that none of the collected sample will be lost and also that no outside particulates enter the train to be included as sample.

Samples will be placed in plastic containers and treated as follows:

<u>Container No. 1</u> - Carefully remove the filter from the filter holder and place in the container and seal with tape.

<u>Container No. 2</u> - Shall contain any loose particulate and acetone washings for the probe, cyclone, cyclone flask, and front half of the filter holder. The inside of the cyclone, cyclone flask, and front half of the filter holder shall be wiped with a rubber policeman, and the inside of the probe with a soft rubber plunger fitted on a stainless steel rod, to loosen adhering organics and carbon.

The loosened particles are then washed into the container with acetone, and the container is sealed with tape.

Container No. 3 - The H_2O from the first three Greenburg-Smith impingers shall be measured within ± 2 milliliters and placed in the container. H_2O rinsings from the back half of the filter holder, the fritted glass support, all connectors, and the first three Greenburg-Smith impingers shall also be placed in this container and the container sealed with tape.

Container No. 4 - Silica gel from the fourth Greenburg-Smith impinger shall be returned to the original container and sealed with tape. A rubber policeman may be used as an aid in removing the silica gel from the impinger, but no liquid may be used.

Container No. 5 - The back half of the filter holder, fritted support, all connectors, and the first three Greenburg-Smith impingers shall be thoroughly rinsed with acetone, and the washings placed in this container and sealed with tape.

11.2 ANALYSIS

Container No. 1 - Transfer the filter and any loose particulate from the sample container to a tared glass weighing dish and desiccate for 24 hours in a desiccator or constant humidity chamber containing a saturated solution of calcium chloride or its equivalent. Weigh to a constant weight and report the results to the nearest 0.1 milligram.

Container No. 2 - Transfer the acetone washings from the probe, cyclone, cyclone flask, and front half of the filter holder to a tared beaker, and evaporate to dryness at ambient temperature and pressure. Desiccate for 24 hours and weigh to a constant weight. Report the results to the nearest 0.1 milligram.

Container No. 3 - Extract organic particulate from the impinger solution with three 25-milliliter portions of chloroform and three 25-milliliter portions of ethyl ether. Combine the ether and chloroform extracts, and transfer to a tared beaker. Evaporate until no solvent remains at about 70°F. This may be accomplished by blowing air filtered through activated charcoal over the sample. Desiccate for 24 hours and weigh to a constant weight. Report the results to the nearest 0.1 milligram.

The impinger solution remaining after extraction of the organics shall be evaporated to dryness on a steam bath or equivalent and the residue weighed to the nearest 0.1 milligram and reported.

the filter holder, fritted support, connectors, and first three Greenburg-Smith impingers to a tared beaker, and evaporate to dryness at ambient temperature and pressure. Desiccate for 24 hours and weigh to a constant weight. Report the results to the nearest 0.1 milligram.

The total particulate weight can be obtained by totaling the weights of the individual sample components.

12. REPORTING RESULTS

Two copies of the report of an incinerator test shall be submitted to the Federal Facilities Section to obtain final approval. Each report shall contain a record of all observations and the log made during each test. The information supplied should include copies of complete sampling data, calculations, the weight and type of refuse charged, tare and final weights of all filters, plus-60-micron count on adhesive samples, and Ringelmann readings of stack gas emissions for each test run.

Each report shall contain the following sections:

1. Introduction. In this section background information regarding the location, manufacture, and size of the incinerator and scrubber shall be presented, together with related information. Also, a schematic of the incinerator should be presented, showing the location of the sampling and measuring points. The distance of sampling location from bends, etc., should be given to the nearest foot.

2. Summary. This section should include a summary of all data collected, together with pertinent comments.

3. Procedure. This section should describe the procedures used in cleaning, adjusting, and firing the incinerator.

4. Analytical Techniques. This section should contain a brief description of all analytical techniques.

5. Data and Calculations. This section should include all data and calculations. Forms for recording and reporting data and calculations shall be obtained from the Federal Facilities Section.

6. Adhesive Paper Samples. The adhesive paper samples should be suitably identified, sprayed with clear lacquer, and submitted.

12.1 PARTICULATES

Particulates shall be reported as grains per cubic foot as sampled, and corrected to dry conditions at 70°F and 29.92 inches mercury and 12 percent carbon dioxide, subtracting off the contribution of carbon dioxide from auxiliary burners on a molar basis.

12.2 ORSAT ANALYSIS

The results of the Orsat analysis shall be reported on a dry basis as the percent of the following gases: carbon dioxide, oxygen, carbon monoxide, and nitrogen.

12.3 ADHESIVE PAPER

The results of the adhesive paper analysis shall be reported as the number of particles over 60 microns per square inch as well as the number of particles over 60 microns per minute for each sample taken, as well as the time of sampling.

REFERENCES

1. Incinerator Institute of America Incinerator Standards, May 1966, New York, New York, 31 pp.

2. "Air Pollution Source Testing Manual," by H. Devorkin, R.L. Chass, A.P. Fudurich, and C.V. Kanter, Air Pollution Control District, Los Angeles County, California, November 1965, 179 pp.

3. City of Cincinnati Air Pollution Control Ordinance No. 119-1965, Division J. Incinerators, Section 2509-8 Incinerator Maintenance and Operation.

ADDENDUM
TO
SPECIFICATIONS FOR INCINERATOR TESTING
AT
FEDERAL FACILITIES

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Bureau of Disease Prevention and Environmental Control
National Center for Air Pollution Control

December 6, 1967

ADDENDUM TO SPECIFICATIONS FOR INCINERATOR TESTING AT FEDERAL FACILITIES

The following material is supplied as a supplement to the publication, "Specifications for Incinerator Testing at Federal Facilities."

ALTERNATIVE METHOD FOR COMPLIANCE TESTING

An alternative method for determining particulate emissions, which has the same stringency as the present method based on carbon dioxide measurements, but permits simpler, less expensive, sampling procedures, may be followed if tester so desires. Since gas washers appear to absorb carbon dioxide, the corrected grain loadings of stack gases from these devices may be excessively high. The alternative method, not being based on carbon dioxide measurements, avoids this possibility.

To use the alternative method, tester must determine the pounds per hour of particulate emitted. To be in compliance, incinerator emissions in pounds per hour must not exceed that indicated in Figures 1 and 2. In general, allowable emissions measured by the alternative method correspond to the amounts allowed in Section 2.2.

In using the alternative method, it is necessary only to sample for particulates and determine emissions in pounds per hour. It is not necessary to measure carbon dioxide during test runs, or determine carbon dioxide emitted from burning auxiliary fuel.

Whichever method for determining compliance is used, the general testing procedures detailed in "Specifications for Incinerator Testing at Federal Facilities," and this Addendum will apply, with the following modification.

In testing with the pounds per hour method, Section 6.2, describing techniques for measuring carbon dioxide from burning auxiliary fuel, and

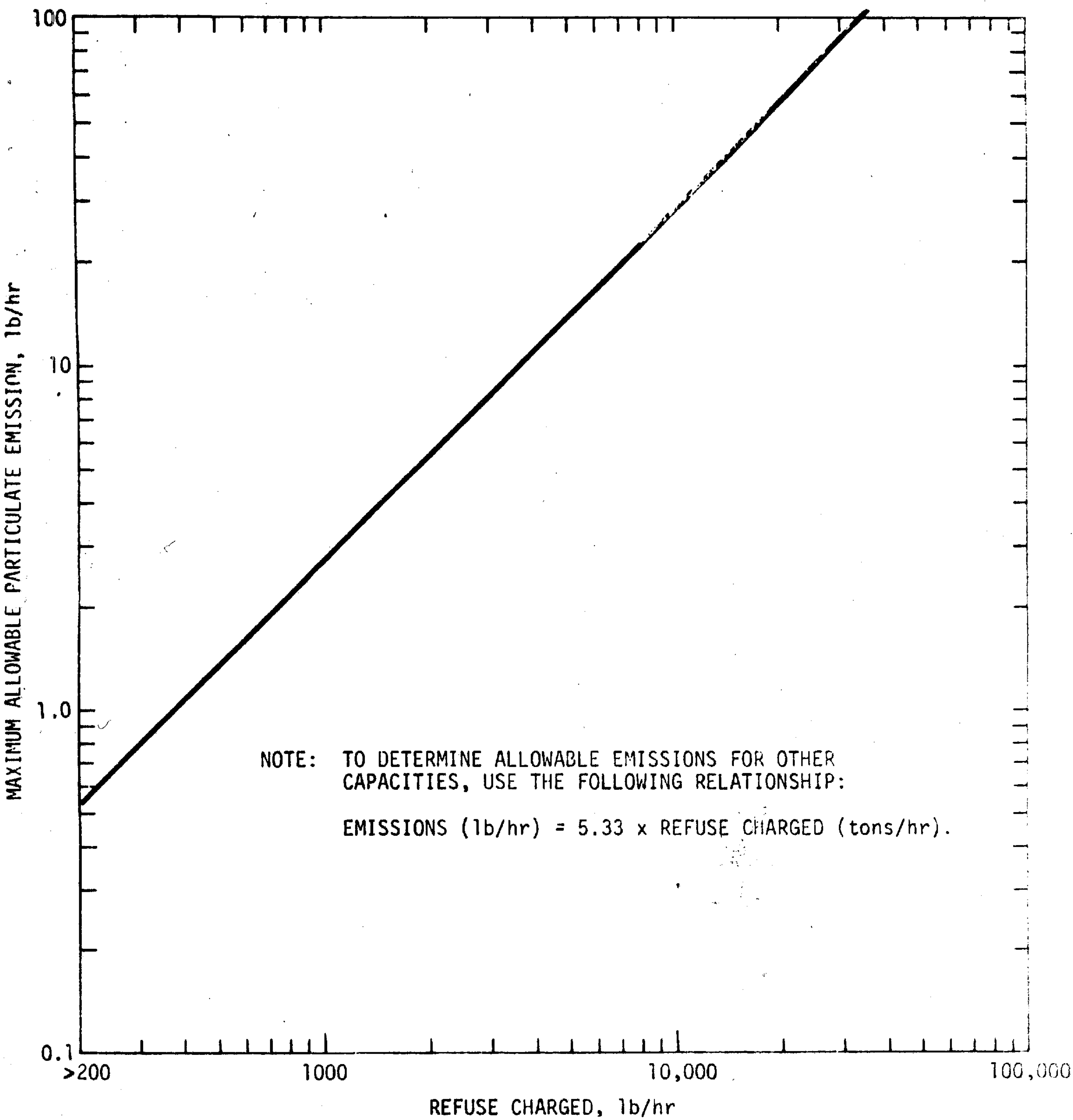


Figure 1. Maximum allowable emission of particulate matter from refuse burning units with capacities greater than 200 pounds per hour.

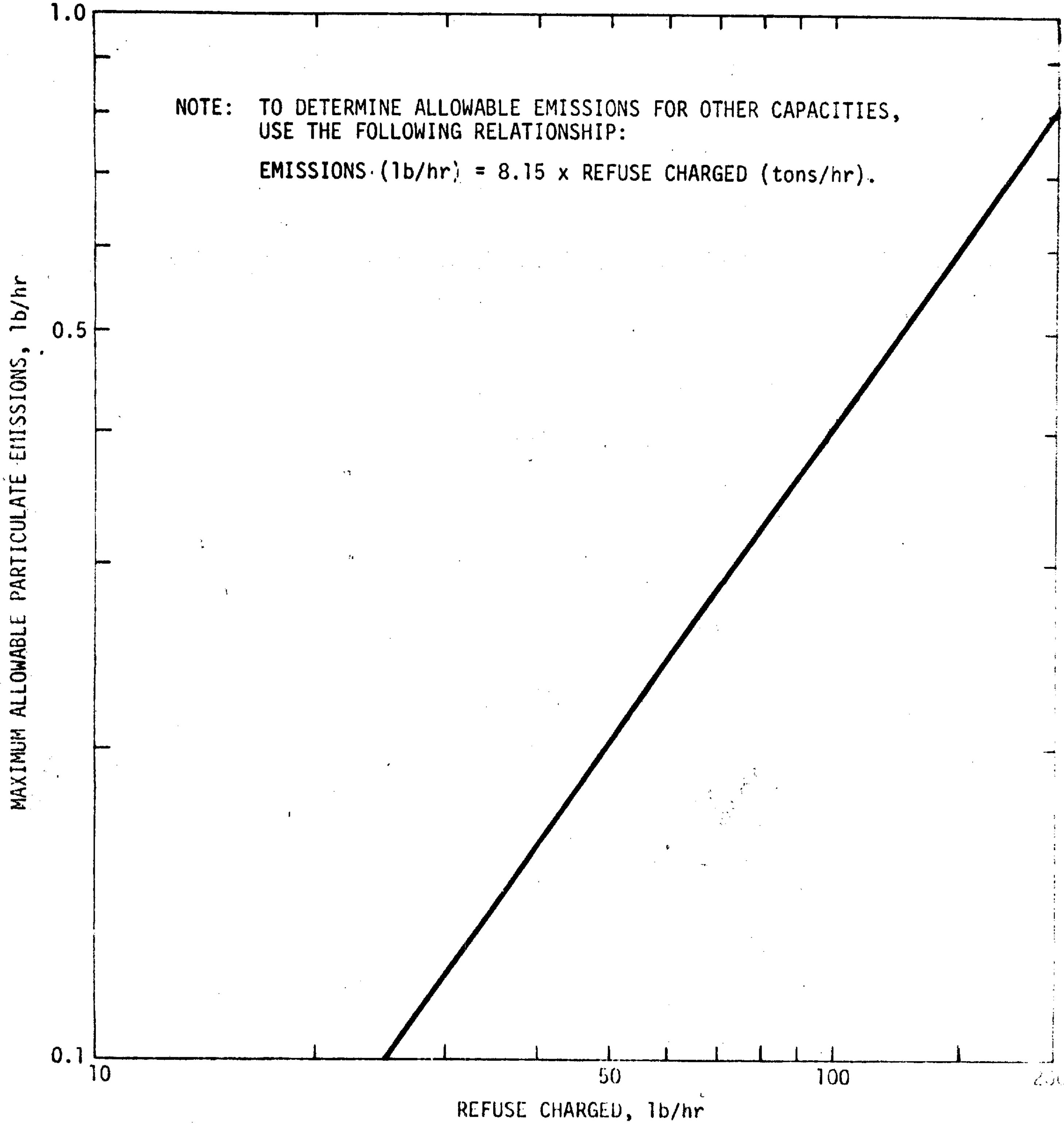


Figure 2. Maximum allowable emission of particulate matter from refuse burning units with capacities of 200 pounds per hour or less.

Section 8, describing the carbon dioxide sampling apparatus, need not be followed. In addition, Section 12.1, reporting results, should be modified so that particulates are reported as pounds of particulate emitted per hour.

PARTICULATE SAMPLING PROCEDURES

When possible, single-point sampling conducted at the point of average stack velocity, should be used for general-refuse incinerators. Such sampling may be conducted under the following conditions:

1. The sampling location is in a vertical duct, at least eight diameters downstream from any bend, expansion, construction, or visible flame and at least two diameters upstream from any bend, etc.
2. The ratio of the maximum to the minimum gas velocity as found from the preliminary velocity traverse is less than 2.

Where these conditions are met, the time of each run shall be 1 hour.

If any of the foregoing conditions are not met, then it will be necessary to perform a sample traverse. In such a traverse the sample probe is placed at each of the velocity traverse points for a length of time given in Table 1. The sample probe shall be moved from one traverse point to another immediately prior to charging.

Table 1. DURATION OF TEST RUNS

Total number of traverse points	Sampling time per point, minutes	Total run time, minutes
1	60	60
4	15	60
6	10	60
8	10	80
9	5	45
>9	5	Number of points x 5

In order to maintain isokinetic conditions during sampling, the nomographs of Figures 3 and 4 may be used. These nomographs, designed for use with the particulate train described in Section 7.4, make it possible to rapidly adjust the sample rate to isokinetic conditions without other computations.

The nomograph of Figure 3, The Operating Nomograph, is used to adjust the sampling rate to maintain isokinetic conditions. The nomograph of Figure 4, The Correction Factor Nomograph, is used to adjust the Operating Nomograph to field conditions. Procedures for using these nomographs are as follows:

1. Determine ΔH_a (the standard orifice pressure drop, in. water), for train by measuring orifice pressure drop at a flow rate of 0.75 cfm, a meter temperature of 70^oF, and a meter pressure of 29.92 in. Hg* (once determined, ΔH_a is constant for a given train and orifice).

2. Estimate probable T_m (meter temperature), often 25^oF above ambient temperature; % H_2O (moisture in stack gas), and P_s/P_m (ratio of stack pressure to meter pressure).

3. Determine Correction Factor "C" using nomograph of Figure 2 as directed thereon and with values estimated above.

---

* An orifice pressure drop (ΔH_b) can be measured at any pressure and temperature, and corrected to standard conditions by the formula below:

$$\Delta H_a = 0.0564 \times \Delta H_b \times \frac{T_b}{P_b}.$$

ΔH_b = Orifice pressure drop @ T_b, P_b and a flow rate of 0.75 cfm.

T_b = Meter temperature, ^{o} Rankin.

P_b = Barometric pressure + orifice pressure drop, in. Hg.

4. Set Correction Factor C on K-Factor Scale of Operating Nomograph (Figure 1) opposite Reference Point 1.

5. Make a rough pitot traverse, and determine minimum, average, and maximum values for Δp (pitot reading, in. water).

6. Measure T_s (the stack temperature), ^{o}F.

7. Draw line from T_s to the values of Δp found in step 5 above. Select a convenient D (nozzle diameter) from the range of values indicated on the probe tip diameter scale.

8. Draw line from T_s through D chosen in step 7 to obtain a value for Δp.

9. Draw a line from the value for Δp obtained in step 8 above to Reference Point 2. on the ΔH (orifice reading) scale to obtain a pivot point on the K-factor scale. This point should be marked for future reference.

10. During sampling, determine the ΔH necessary for isokinetic sampling by aligning pitot readings (Δp) with the K-factor pivot point determined in step 9 above. Adjust sample flow rate to produce desired ΔH or orifice manometer. The train will then be sampling isokinetically.

11. If T_s changes, repeat steps 6 through 10 above.

DATA AND CALCULATION REPORTING FORMS

The data and calculation forms provided herein are for recording data and for calculating and reporting test results in a standard manner. An instruction sheet accompanying the forms explains how they should be used. The forms are to be submitted with the other information required under Section 12, Reporting Results, of the original publication.

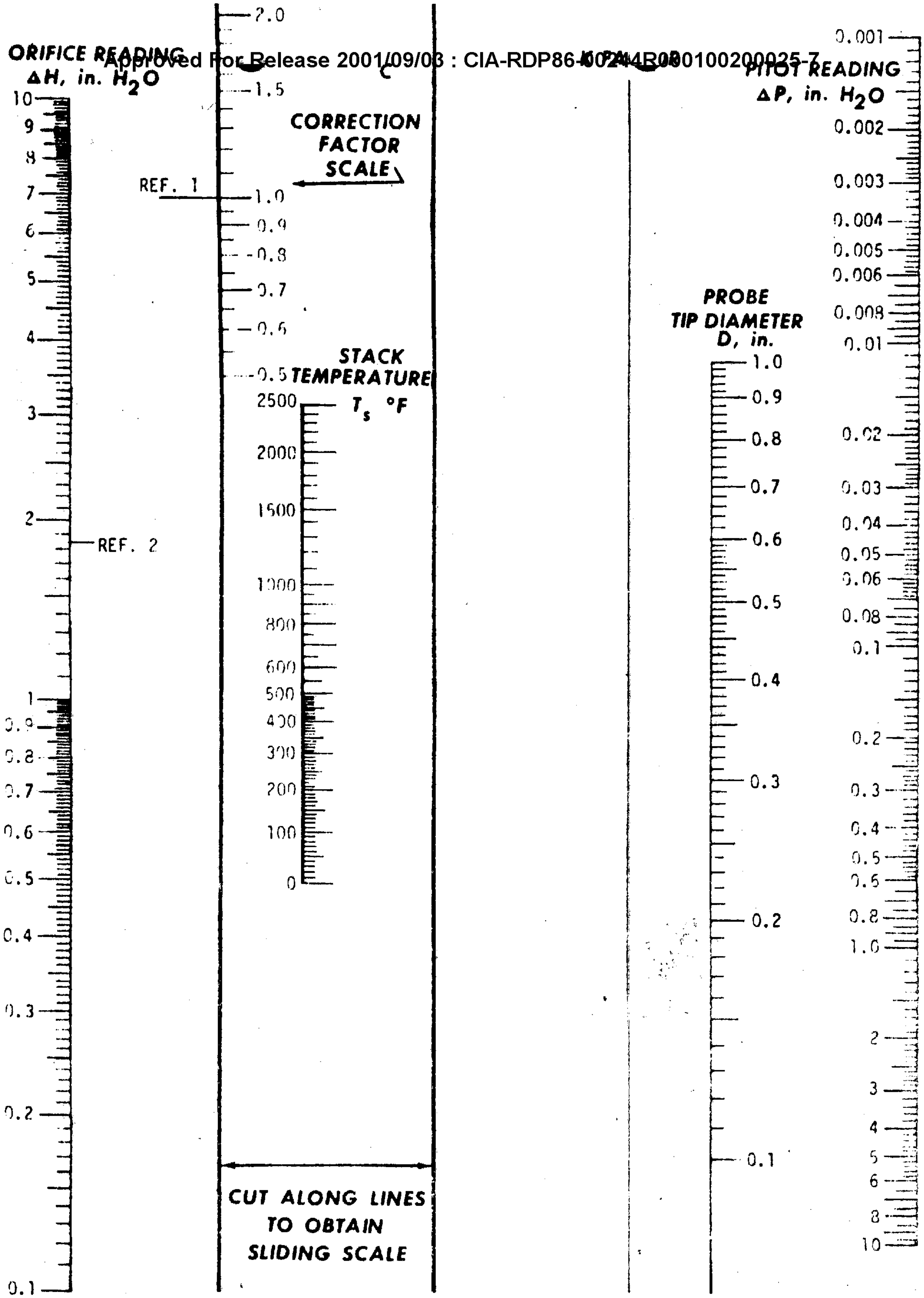
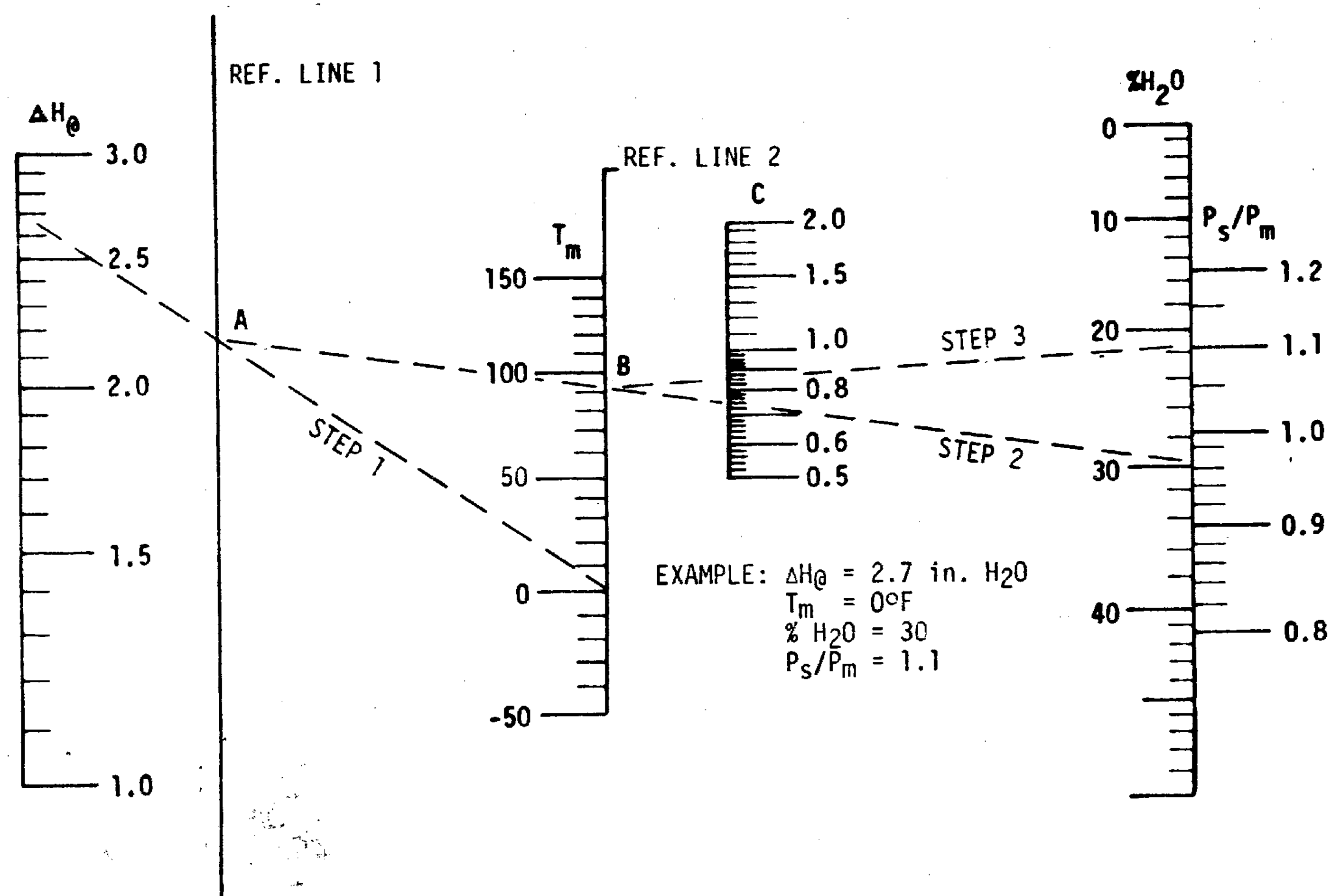


Figure 3 Operating nomograph.



TO FIND C:

STEP 1: DRAW LINE FROM $\Delta H_@$ TO T_m TO OBTAIN POINT A ON REF. LINE 1.

STEP 2: DRAW LINE FROM A TO % H_2O AND READ B ON REF. LINE 2.

STEP 3: DRAW LINE FROM POINT B TO P_s/P_m, AND OBTAIN ANSWER OF 0.85 FOR C.

Figure 4 Correction factor nomograph for Figure 3 .

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Public Health Service
National Center for Air Pollution Control

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Jan. 1973

Instructions for Filling Out Source Testing Calculation Forms for Incinerators

To complete these forms, the following instructions should be adhered to:

1. When using the pounds per hour method to determine compliance, only Parts 8, 9 and 10 need be completed. If the grains per standard cubic foot corrected to 12 % CO_2 method is used to determine compliance, instructions 2 through 6 should be followed.

2. Fill out completely Parts 9 and 10.

3. Fill out completely Tables in Part 3, page 1; Part 4, page 1; Part 5, page 1; Part 6, page 1; and Part 7, page 1.

4. Fill out Summary of Test Data Sheet obtaining information from appropriate pages.

5. Use formulas in order as numbered in left hand margin starting in Part 3, page 1.

6. Transfer all appropriate data to Summary of Results Sheet, Part 1.

Note: These forms have been especially designed for use with the sampling trains described in "Specifications for Incinerator Testing at Federal Facilities."

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Jan. 1973

SUMMARY OF RESULTS

Incinerator Test

Run No. _____

1. Name of firm ______________________________
2. Location of plant ______________________________
3. Type of incinerator ______________________________
4. Control equipment ______________________________
5. Sampling point location ______________________________
6. Material incinerated ______________________________
7. Weight of material incinerated ______________________________
8. Pollutants sampled ______________________________

____

9. Time of particulate test:

Date ______________, Begin ______________, End ______________

Operating Variables

10. Scrubber pressure drop, in. H_2O __________
11. Scrubber H_2O rate, gpm __________
12. Primary chamber draft, in. H_2O Overfire ______ Underfire ______
13. Secondary chamber temperature, ^{o}F __________
14. Stack temperature (T_{hd}), ^{o}F __________

Emission Data

15. Stack flow rate (V_{db}), scfm ________
16. Water vapor in stack gas (V_{cg}), % by volume ________
17. Excess air at sampling point (V_{b1}), % ________

	grains/cf at stack conditions	grains/scf	grains/scf at 12 % CO_2 *	lb/hr
18. Particulate - probe, cyclone	C_{as}=	C_{am}=	C_{ap}=	C_{av}=
19. Particulate - probe, cyclone, filter	C_{at}=	C_{an}=	C_{aq}=	C_{aw}=
20. Total particulate (includes impinger catch)	C_{au}=	C_{ao}=	C_{ar}=	C_{ax}=

21. Percent isokinetic for particulate train I_{ax}= ________
22. CO_2 in stack gas from burners**, % volume (dry) V_{bn}= ________
23. CO_2 in stack gas from waste, % volume (dry) V_{ba}= ________
24. O_2 in stack gas from waste and burners, % volume (dry) V_{bh}= ________
25. CO in stack gas from waste and burners, % volume (dry) V_{bg}= ________
26. N_2 in stack gas from waste and burners, % volume (dry) V_{bi}= ________
27. Sticky paper, particles/in.^{2} 60 microns and above ________
28. Sticky paper, particles/min. 60 microns and above ________

Legend: NM - not measured
scf = Standard cubic foot, i.e., dry gas at 70°F and 29.92 in. Hg.
Stack conditions: Stack temperature and stack pressure including moisture.

* Correction to 12 % CO_2 made using % CO_2 from waste only.

** % CO_2 from burner corrected to test conditions.

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SUMMARY OF TEST DATA

Date ______________ Run No. ______________

Particulate Sampling Train

1.	Sampling nozzle diameter, in.	D_{av} =	______
2.	Sampling time, min.	T_{aw} =	______
3.	Sample gas volume - meter condition, cf	V_{ac} =	______
4.	Average meter temperature, ^oF	T_{ai} =	______
5.	Average orifice pressure drop, in. H_2O	P_{af} =	______
6.	Particulate collected - probe and cyclone, mg	W_{aj} =	______
7.	Particulate collected - probe, cyclone and filter, mg	W_{ak} =	______
8.	Particulate collected - total, mg	W_{al} =	______

Velocity Traverse - Burner Only

9.	Stack area, in.^{2}	S_{dd} =	______
10.	Average stack pressure, in. Hg (absolute)	P_{hc} =	______
11.	Average stack temperature, ^oF	T_{hd} =	______
12.	Average $\sqrt{\text{velocity head x stack temperature}}$	S_{he} =	______
13.	Moisture in stack gas from burners, % by volume	V_{hi} =	______

Velocity Traverse During Test - Burner and Waste

14.	Stack area, in.^{2}	S_{dd} =	______
15.	Average stack pressure, in. Hg (absolute)	P_{di} =	______
16.	Average stack temperature, ^oF	T_{df} =	______
17.	Average $\sqrt{\text{velocity head x stack temperature}}$	S_{de} =	______

Stack Moisture Content

18.	Total water collected by train, ml	V_{ce} =	______

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NO 68R-1056
APPROVAL EXPIRES
Jan. 1973

PARTICULATE SAMPLING TRAIN DATA AND CALCULATIONS

Nozzle diameter (D_{av}), in. = ________

Barometric pressure (P_{aa}), in. Hg = ________

Sampling point location ________ Run No. ________

Clock time	Point No.	Gas Meter: Reading (V_{ac}) cf	Gas Meter: Temp. in °F	Gas Meter: Temp. out °F	Orifice Δ P in. H_2O
Net time min		Net	Average	Average	Average
(T_{aw})=		(V_{ac})=	(T_{ad})=	T_{ae})=	(P_{af})=

(1) A. Average meter temperature $= \frac{T_{ad} + T_{ae}}{2} = T_{ai} =$ ________

(2) B. Dry gas sample volume @ standard conditions, cf

$$= 17.7 \times V_{ac} \times \frac{P_{aa} + \frac{P_{af}}{13.6}}{(T_{ai} + 460)} = V_{ab} =$$ ________

NCAP-18 (12/67

Laboratory Data

Particulate - probe and cyclone (W_{aj}), mg = ________

Particulate - probe, cyclone, and filter (W_{ak}), mg = ________

Particulate - total (includes impinger washings) (W_{al}), mg = ________

Particulate Concentration Calculations

In grains/scf

(3) A. Particulate - probe and cyclone, grains/scf

$$C_{am} = 0.0154 \times \frac{W_{aj}}{V_{ab}} = \_\_\_\_\_\_\_\_$$

(4) B. Particulate - probe, cyclone, and filter, grains/scf

$$C_{am} = \frac{0.0154 \times W_{ak}}{V_{ab}} = \_\_\_\_\_\_\_\_$$

(5) C. Particulate - total, grains/scf
(Go to Part 6, page 1)

$$C_{ao} = \frac{0.0154 \times W_{al}}{V_{ab}} = \_\_\_\_\_\_\_\_$$

In grains/scf @ 12 % CO_2

(17) D. Particulate - probe and cyclone, grains/scf @ 12 % CO_2

$$C_{ap} = C_{am} \times \frac{12}{V_{ba}} = \_\_\_\_\_\_\_\_$$

(18) E. Particulate - probe, cyclone, and filter, grains/scf @ 12 % CO_2

$$C_{aq} = C_{an} \times \frac{12}{V_{ba}} = \_\_\_\_\_\_\_\_$$

(19) F. Particulate - total, grains/scf @ 12 % CO_2

$$C_{ar} = C_{ao} \times \frac{12}{V_{ba}} = \_\_\_\_\_\_\_\_$$

In grains/cf @ stack conditions

(20) G. Particulate - probe and cyclone, grains/cf @ stack conditions

$$C_{as} = \frac{17.7 \times C_{am} \times P_{di} \times Mch}{(T_{df} + 460)} = \_\_\_\_\_\_$$

(21) H. Particulate - probe, cyclone, and filter, grains/cf @ stack conditions

$$C_{at} = \frac{17.7 \times C_{an} \times P_{di} \times Mch}{(T_{df} + 460)} = \_\_\_\_\_\_$$

(22) I. Particulate - total, grains/cf @ stack conditions

$$C_{au} = \frac{17.7 \times C_{ao} \times P_{di} \times Mch}{(T_{df} + 460)} = \_\_\_\_\_\_$$

In lb/hr

(23) J. Particulate - probe and cyclone, lb/hr

$$C_{av} = 0.00857 \times C_{am} \times V_{db} = \_\_\_\_\_\_$$

(24) K. Particulate - probe, cyclone, and filter, lb/hr

$$C_{aw} = 0.00857 \times C_{an} \times V_{db} = \_\_\_\_\_\_$$

(25) L. Particulate - total, lb/hr

$$C_{ax} = 0.00857 \times C_{ao} \times V_{db} = \_\_\_\_\_\_$$

(26) M. % isokinetic $= \dfrac{1032 \times (T_{df} + 460) \times V_{ab}}{V_{dh} \times T_{aw} \times P_{di} \times M_{ch} \times (D_{av})^2} = I_{ax} = \_\_\_\_\_\_$

(Go to Part 7, p. 1)

V_{ba} from Orsat data and calculation sheet (part 7).

V_{db}, T_{df}, V_{dh}, P_{di}, from velocity data and calculation sheet for test (Part 5).

M_{ch} from moisture content data and calculation sheet (Part 6).

D_{av} from particulate sampling train data and calculation sheet (Part 3).

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VELOCITY TRAVERSE DATA AND CALCULATION SHEET

(Burners Only)

Date ____________ Time ________ Run No. ______

Sampling point location ____________

Stack area (S_{dd}), in.^{2} ____________

Wet bulb temperature (T_{hj}), ^oF ____________

Dry bulb temperature (T_{hk}), ^oF ____________

Barometric pressure (P_{hl}), in. Hg absolute = ________

Note: Calculations for S-type pitot tube, C = 0.85

Drawing of stack cross section

Point No.	Distance from ref. point, in.	Stack press. (P_{hm}) in. Hg. (gage)	Stack Temperature (T_{hd}), ^oF	Stack Temperature (T_{hd} + 460), ^oR	Velocity head (V_a), in. H_2O	$V_a \times (T_{hd} + 460)$	$\sqrt{V_a \times (T_{hd} + 460)}$
		Avg = ____	Avg = ____				Avg (S_{he}) = ____

in. Hg (abs) =

(P_{hc}) = P_{hm} + P_{hl} =

(9) A. Moisture in stack gas, from wet and dry bulb temperatures using psychrometric charts (V_{hi}), % = ________

(10) B. Mole fraction of dry gas

$$= \frac{100-V_{hi}}{100} = M_{hg} = \text{\_\_\_\_\_\_\_\_}$$

(11) C. Stack velocity @ P_{hc} and T_{hd} (stack conditions, includes moisture), fpm

$$= 4350 \times S_{he} \left[\frac{1}{P_{hc} \times (M_{bk} \times M_{hg} + 18(1-M_{hg}))} \right]^{1/2} = V_{hf} \text{\_\_\_\_\_\_\_\_}$$

(12) D. Stack volume @ standard conditions, scfm

$$= \frac{0.123 \times V_{hf} \times S_{dd} \times P_{hc} \times M_{hg}}{(T_{hd} + 460)} = V_{hh} = \text{\_\_\_\_\_\_\_\_}$$

(Go to Part 5, p. 2)

M_{bk} from Orsat data and calculation sheet (Part 7).

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NO. 68R-1056
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Jan. 1973

VELOCITY DATA AND CALCULATION SHEET FOR TEST

(Burners and Waste)

Date ________________ Time ________

Sampling point location ____________ Run No. ______

Stack area (S_{dd}), in.^{2} ____________

Note: Calculations for S-type pitot tube, C = 0.85

Drawing of stack cross section

Point No.	Distance from ref. point, in.	Stack press. (P_{dj}), in. Hg (gage)	Stack temperature (T_{df}), ^oF	(T_{df} + 460), ^oR	Velocity head (V_b), in. H_2O	V_b x (T_{df} + 460)	$\sqrt{V_b \text{ x } (T_{df} + 460)}$
		Avg = ____	Avg = ____				Avg (S_{de}) = ____

in. Hg abs) =

$(P_{di}) = P_{dj} + P_{aa}$ = ____

P_{aa} from particulate sampling train sheet (Part 3).

NCAP-20 (12/67)

(13) A. Stack velocity @ P_{di} and T_{df} (stack conditions), fpm

$$= 4350 \times S_{de} \times \left[\frac{1}{P_{di} \times M_{ca}}\right]^{1/2} = V_{dh}$$ ________

(14) B. Stack volume @ standard conditions, scfm

$$= 0.123 \times \frac{V_{dh} \times S_{dd} \times M_{ch} \times P_{di}}{(T_{df} + 460)} = V_{db} =$$ ________

(Go to Part 7, p. 2.)

M_{ca}, M_{ch} from stack moisture data and calculation sheet (Part 6).

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STACK MOISTURE CONTENT DATA AND CALCULATIONS FOR TEST

Date ______________________

Run No.				
H_2O condensed in impingers (V_{cb}), ml				
H_2O absorbed by silica gel (V_{cd}), ml				
Total H_2O collected $= V_{ce} = (V_{cb} + V_{cd})$, ml				
Vol of H_2O vapor @ 70°F and 29.92 in. Hg $= 0.0474 \times V_{ce}$ $= (V_{cf})$, cf				
Moisture in stack gas $= (V_{cg})$, % (from formula below)				
Mole fraction dry gas, $= (M_{ch})$ (from formula below)				
Molecular weight of stack gas (M_{ca}) (from formula below)				

(6) A. Moisture in stack gas (V_{cg}), %

$$= \frac{100 \times V_{cf}}{V_{ab} + V_{cf}}$$

(7) B. Mole fraction dry gas (M_{ch})

$$= \frac{100 - V_{cg}}{100}$$

(8) C. Molecular weight of stack gas

$$M_{ca} = M_{bj} \times M_{ch} + 18(1 - M_{ch})$$

(Go to Part 4, p. 2.)

V_{ab} from particulate data and calculation sheet (Part 3).

M_{bj} from Orsat data sheet (Part 7).

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FORM APPROVED
BUDGET BUREAU
NO 68R-1056
APPROVAL EXPIRES
Jan. 1973

ORSAT DATA AND CALCULATION SHEET

Orsat Analysis - Burner Only (From bag sample)

Sampling point location ______________________

Date ____________________ Time ____________

	Analysis 1	Analysis 2	Analysis 3	Avg	x = mole.wt	wt/mole (dry)
CO_2 (V_{bb}), % vol (dry)					44/100	
CO (V_{bc}), % vol (dry)					28/100	+
O_2 (V_{bd}), % vol (dry)					32/100	+
N_2 (V_{be}), % vol (dry)					28/100	+

M_{bk} = Avg molecular wt of dry stack gas = ________

Orsat Analysis for Test - Waste and Burners (From bag sample)

Date ____________________ Time __________ Run No. __________

Sampling point location ______________________

	Analysis 1	Analysis 2	Analysis 3	Avg	x = mole wt	wt/mole (dry)
CO_2 (V_{bf}) % vol (dry)					44/100	
CO (V_{bg}), % vol (dry)					28/100	+
O_2 (V_{bh}), % vol (dry)					32/100	+
N_2 (V_{bi}), % vol (dry)					28/100	+

M_{bj} = Avg molecular wt of dry stack gas = ________

(28) A. Excess air, %

$$= \frac{100 \times (V_{bh} - \frac{V_{bg}}{2})}{0.264 \times V_{bi} - (V_{bh} - \frac{V_{bg}}{2})} = V_{bl} = \underline{\qquad\qquad}$$

(Transfer all answers to summary of results)

(15) B.* CO_2 contributed by burner, % by volume of stack gas corrected to test conditions.

$$V_{bn} = V_{bb} \times \frac{V_{hh}}{V_{db}} \times G_{bm} = \underline{\qquad\qquad}$$

(16) B. CO_2 in stack gas from waste, % vol (dry)
(Go to Part 3, p. 2)

$$= V_{bf} - V_{bn} = V_{ba} = \underline{\qquad\qquad}$$

V_{db} from velocity data and calculation sheet for test (Part 5).

V_{hh} from velocity traverse data and calculation sheets (Part 4).

G_{bm} from incinerator data and calculation sheet (Part 10).

Note: Above calculation corrects CO_2 of burner to stack test conditions.

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* Note: If CO_2 from burners is determined from an analysis of the natural gas flow, the following equation can be used in place of equations (15) and (16) to calculate (V_{ba}).

Z = CO_2 from burners, scfm (Determine from natural gas flow rate) ________

$$V_{ba} = \frac{V_{db} \times V_{bf} - (Z \times G_{bm} \times 100)}{V_{db}} = \underline{\qquad\qquad}$$

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POUNDS PER HOUR EMISSION CALCULATION

Total particulate collected by train, grams	W_{1a} = ________
Area of sampling nozzle, in.^{2}	W_{1b} = ________
Area of stack, in.^{2}	W_{1c} = ________
Time of particulate test, min.	W_{1d} = ________

Emissions, lbs/hr

$$= \frac{0.132 \times W_{1a} \times W_{1c}}{W_{1b} \times W_{1d}} =$$

C_{ay} = ________

Note: Sufficient data and calculations should be included to show that the particulate train was operated within 10 percent of isokinetic conditions. Comparison of the probe sampling velocity to the stack gas velocity will be sufficient for this purpose. To make this comparison it will be necessary to measure:

1. Stack temperature
2. Stack velocity
3. Sampled gas volume and temperature
4. Moisture in sampled gas

NCAP-40 (12/67)

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STICKY PAPER DATA AND CALCULATIONS

Date ______________________________

Stack area, $in.^2$ ______________________

Sampling point location ________________

Run No. ____________________________

Time	Part/$in.^2$/min > 60 microns	Part/min >60 microns
	Avg	Avg

Note: Particles/min = stack area x part/$in.^2$/min.

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INCINERATOR OPERATING DATA AND CALCULATION SHEET

Date ______________________

Run No. ______________________

Clock time	Material charged, lb	Primary chamber draft: Overfire, in. H_2O	Primary chamber draft: Underfire, in. H_2O (Optional)	Secondary chamber: Temp. °F	Stack opacity: %	Comments
	Net = ___	Avg = ___	Avg = ___	Avg = ___	Avg = ___	

Fraction of time all burners are operating (G_{bm}) = ______

NCAP-27 (12/67)

DEFINITIONS

Standard conditions - 70°F and 29.92 in. Hg

scf - Standard cubic foot of dry gas @ 70°F and 29.92 in. Hg

scfm - Standard cubic foot per minute of dry gas @ 70°F and 29.92 in.Hg

Stack conditions - stack temperature, pressure, and moisture.

LIST OF SYMBOLS

Part 3. Particulate sampling train data and calculation sheet

C_{am}, Particulate-probe and cyclone, grains/scf

C_{an}, particulate-probe, cyclone and filter, grains/scf

C_{ao}, Particulate-total, grains/scf

C_{ap}, particulate-probe, cyclone and filter, grains/scf @ 12 % CO_2

C_{aq}, particulate-probe, cyclone and filter, grains/scf @ 12 % CO_2

C_{ar}, particulate-total, grains scf 12 % CO_2

C_{as}, particulate-probe and cyclone, grains/scf @ stack conditions

C_{at}, particulate-probe, cyclone and filter, grains/cf @ stack conditions

C_{au}, particulate-total particulate, grains/cf @ stack conditions

C_{av}, particulate - probe and cyclone, lb/hr

C_{aw}, particulate - probe, cyclone and filter, lb/hr

C_{ax}, particulate - total, lb/hr

D_{av}, sampling nozzle diameter, in.

P_{aa}, barometric pressure, in.Hg (Absolute)

P_{af}, orifice pressure drop, in. H_2O

T_{ad}, gas meter inlet temperature, ^oF

T_{ae}, gas meter exit temperature, ^oF

T_{ai}, average gas meter temperature, ^oF

T_{aw}, net time of test, minutes

T_{ax}, percent isokinetic

V_{ab}, volume of dry gas sampled @ standard conditions, ft^3

V_{ac}, Volume of dry gas sampled @ meter conditions, ft^3

W_{aj}, particulate-probe and cyclone, mg

W_{ak}, particulate-probe, cyclone and filter, mg

W_{al}, particulate - total, mg

Part 4. Velocity traverse data and calculation sheet (burners only)

M_{hg}, mole fraction dry gas

P_{hc}, stack pressure, in.Hg. (absolute)

P_{hl}, barometric pressure, in. Hg.(absolute)

P_{hm}, stack pressure, in. Hg. (gage)

S_{dd}, stack area, $in.^2$

S_{he}, average $\sqrt{\text{Velocity head x stack temperature.}}$

T_{hd}, average stack temperature, ^oF

T_{hj}, wet bulb temperature, ^oF

T_{hk}, dry bulb temperature, ^oF

V_a, Velocity head of stack gas (burner only) in. H_2O

V_{hf}, stack gas velocity, fpm @ stack conditions

V_{hh}, stack gas volume @ standard conditions, scfm

V_{hi}, moisture in stack gas by volume, %

Part 5. Velocity data and calculation sheet for test (burners and waste)

P_{di}, stack pressure, in Hg (absolute)

P_{dj}, stack pressure, in. Hg (gage)

S_{dd}, stack area, in^2

S_{de}, average $\sqrt{\text{Velocity head x stack temperature}}$

T_{df}, stack temperature, ^oF

V_b, velocity head of stack gas burner and waste, in. H_2O

V_{db}, stack gas volume @ standard conditions, scfm

V_{dh}, stack velocity @ stack conditions, fpm

Part 6. Stack moisture content data and calculation sheet

M_{ca}, molecular weight of stack gas

M_{ch}, mole fraction of dry gas

V_{cb}, H_2O condensed in impingers, ml

V_{cd}, H_2O absorbed silica gel, ml

V_{ce}, total H_2O collected, ml

V_{cf}, volume of water vapor collected, cu ft @ standard conditions

V_{cg}, moisture in stack gas by volume, %

Part 7. Orsat data and calculation sheet

G_{bm}, fraction of test time all burners are operating

M_{bj}, molecular weight of dry stack gas (waste and burner)

M_{bk}, molecular weight of dry stack gas (burner only)

V_{ba}, % CO_2 from waste (dry basis)

V_{bb}, % CO_2 from burner (dry basis)

V_{bc}, % CO from burner (dry basis)

V_{bd}, % O_2 from burner (dry basis)

V_{be}, % N_2 from burner (dry basis)

V_{bf}, % CO_2 from waste and burner (dry basis)

V_{bg}, % CO from waste and burner (dry basis)

V_{bh}, % O_2 from waste and burner (dry basis)

V_{bi}, % N_2 from waste and burner (dry basis)

V_{bl}, % excess air at sampling point

V_{bn}, CO_2 contributed by burner, % by volume of stack gas corrected to test conditions